

## FUEL CELL WITH INTEGRATED HEAT EXCHANGER

[0001] This is a continuation of international application PCT/EP02/02276, with an international filing date of March 2, 2002, the entire disclosure of which is incorporated herein by reference.

[0002] This application also claims the priority of prior German application 101 13 002.3, filed March 17, 2001.

### BACKGROUND AND SUMMARY OF THE INVENTION

[0003] It is a known fact for fuel cells, especially high temperature fuel cells (such as SOFC fuel cells), that the cathode-side gaseous reactant (e.g., the reaction air) should be pre-warmed to bring it to the required reaction temperature. This is conventionally performed in a separate high temperature heat exchanger. Such a heat exchanger, however, is bulky, heavy and expensive. Moreover, such a heat exchanger necessitates complex tubing as well as a cost-intensive regulating and control system.

[0004] It is an object of the present invention to provide a fuel cell which effects the necessary warming of the cathode-side gaseous reactant without the aforementioned disadvantages.

[0005] Accordingly, an end or intermediate plate, which is arranged on or between the various electrolyte/electrode units (individual cell), is designed so that, in terms of

flow before an inlet region, particularly a cathode-side inlet region, a heat exchange region is incorporated, in which heat is removed from an anode side and thus the gaseous reactant (e.g., air) is heated to the required reaction temperature.

[0006] A core idea of the present invention thus is to integrate a heat exchanger, for example, in a bipolar plate, and to conduct the gaseous reactant that must be heated (e.g., the air) along the hot anode side. The gaseous reactant is not supplied to the appropriate electrode (e.g., cathode) for generating power until it has flowed through this area acting as a heat exchanger.

[0007] The end or intermediate plate can be designed so that, for example, a reversal of the flow direction of the gaseous reactant is accomplished. In this way, the gaseous reactant can be conducted through the heat exchanger in a serpentine fashion in order to enable even better heat transfer in the heat exchanger.

[0008] The end or intermediate plate (e.g., bipolar plate) preferably contains three flow regions, specifically an anode flow section between the end or intermediate plate and an adjacent anode of an individual cell, a return current heat exchange section adjacent to the anode flow section, and a cathode flow section between the end or intermediate plate and a cathode of another individual cell.

[0009] Pursuant to a particularly preferred design, the end or intermediate plate is composed of at least two separate partial elements that can be joined together. At least

part of the heat exchange section is included between the two partial elements, and the heat exchange section is connected in terms of flow with the region that later forms the cathode section. If a baffle is arranged between the two partial elements, a serpentine-conducted flow is easy to produce, so that the direction of flow of the gaseous reactants in both partial sections is in the opposite direction.

[0010] For a design of the individual flow regions, spacer elements, e.g., in the shape of nubs, can be provided on the individual sides of the end or intermediate plates, as well as between the partial elements, so that the spacer elements rest either against each other or against the individual cells. The nubs can be produced through an embossing or deposition method and shaped as required.

[0011] A simple design of the present invention is described in the following in more detail while referencing the attached figure.

#### BRIEF DESCRIPTION OF THE DRAWING

[0012] The attached drawing figure is a rough sketch providing a partial sectional view of a fuel cell according to the invention.

#### DETAILED DESCRIPTION OF THE INVENTION

[0013] As shown in the drawing figure, a fuel cell according to the invention has a first individual cell 12, comprising a cathode 40, electrolyte 42 and anode 44, and a second individual cell 14, comprising a cathode 46, electrolyte 48 and anode 50. Both

individual cells represent a ceramic electrolyte/electrode unit, which is not explained in detail and between which an intermediate plate, in this case a bipolar plate, is arranged. The bipolar plate serves to introduce the various gaseous reactants in the respective electrode sides (anode 44, cathode 46) of the individual cells 12, 14 as well as to produce electric conductivity.

[0014] The bipolar plate in the present case is designed as a two-piece unit, including a first nub plate 20 and a second nub plate 24, which is designed substantially laterally reversed in relation to the bisecting line of the drawing.

[0015] Each nub plate 20 and 24 comprises a plate, on the bottom and top surfaces of which a plurality of nubs (reference numbers 22 and 26) are arranged, respectively. These nubs 22, 26 create both a space to the electrodes (anode, cathode) of the various individual cells 12 and 14 and a space between the two nub plates 20 and 24 as such.

[0016] The design of the nubs, which in the present case were produced by an embossing method in the plates, creates various flow regions in the developing clearance spaces, for one on the anode side a first flow region 16 between the nub plate 22 and the anode of the individual cell 12, in which a gaseous reactant, for example  $H_2$ , natural gas or gas/diesel reformat, can be introduced. In the present case, this is indicated in the sketch by the four-point stars in the anode flow region 16. The flow of the gaseous reactant here occurs into the focal plane, i.e., vertical to the image.

[0017] A baffle 36 is arranged between the two nub plates 20 and 24 of the bipolar plate. The baffle both separates the flow regions developing between the two nub plates 20 and 24 from each other and creates a deflection region 32, in which the direction of flow of the second gaseous reactant – here air – is reversed. The air is conducted in the direction of the arrow into the bipolar plate and initially moves in the flow region 30 created by the nubs along the anode or past the anode-side flow region 16. This creates a heat transfer from the hot anode side to the air that is initially still at room temperature or that has been pre-warmed in a simple configuration. The air thus warms up. After the air current has flowed almost completely across the length of the individual cell, it is reversed at the end of the baffle 36, wherein the air flow then – also in the direction of the arrow – crosses the bipolar plate again essentially across its width beneath the baffle 36 in the opposite direction to the upper flow direction. This also heats the air. On the second flow region 34 on the right end of the figure, the direction of flow is reversed again, caused by an area of the baffle 36 that is bent at a 90° angle, so that the air is guided into the cathode flow region 18. The air, which has meanwhile been brought to reaction temperature, is then supplied to the cathode of the individual cell 14 and used to generate power.

[0018] The present invention thus incorporates the bipolar plate into a heat exchanger, comprising the heat exchanger chambers 30 and 34. The air flows through these chambers before the reactant reaches the cathode flow region. The fuel cell, which is operated at a high temperature, heats the air sufficiently to the reaction temperature so that a separate complex heat exchanger arranged upstream is not required. In this

way, air flow can be reduced compared to existing configurations. Beyond that, the gravimetric and volumetric power density levels can be increased while simultaneously lowering manufacturing costs. Moreover it is possible to avoid ceramic-incompatible thermal stress. And finally the efficiency of such a fuel cell can be lowered by reducing the parasitic power requirements of the reaction air blower by having the possibility of drastically reducing the need for air circulation.

[0019] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.